

NATIONAL ACCELERATOR LABORATORY

Physics Note

Casting Shadows on Septa

A. Maschke

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This note is to suggest a method for reducing the losses on septum magnets. The principal is very simple. Consider a thin septum with beam impinging on its edge. Some particles will coulomb scatter out, and others will make strong interactions in the septum. The game is to get most of them to scatter out without interacting with a nucleus.

The displacement of a particle due to multiple coulomb scattering can be written as:

$$Y_{\text{rms}} \approx \frac{Kl^{3/2}}{\sqrt{\alpha}} \quad \text{where } \alpha = \text{rad. length}$$

If the septum has a width w , then the length of path is given by:

$$w/2 = Y_{\text{rms}} = \frac{Kl^{3/2}}{\sqrt{\alpha}}$$

$$\text{then } l = \left(\frac{w}{2K} \sqrt{\alpha} \right)^{2/3}$$

Now if the interaction length is taken as β , the fraction which interacts, for $l \ll \beta$ is given by:

$$f \approx \frac{l}{\beta} = \left(\frac{w}{2K} \right)^{2/3} \frac{\alpha^{1/3}}{\beta}$$

Now we can write $\alpha = \alpha_0 / \rho$, where α_0 is the radiation length in terms of grams/cm², say, and ρ is the density. Making a similar substitution for β we find:

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$$f = \left(\frac{w}{2K} \right)^{2/3} \left(\frac{\alpha_o}{\beta_o} \right)^{1/3} \times \rho^{2/3}$$

Within limits one will improve things by picking a material with the best $\alpha_o^{1/3} / \beta_o$ factor. Tungsten is a good choice, for instance. The only real factor one has in reducing f is to make the density low. This can be done, for instance, by making the "septum" of wires spaced at appropriate intervals.

In theory, f could be made vanishingly small if the density is chosen low enough. However $l \propto \rho^{-1/3}$, and in practical situations there are length restrictions. Also, the finite emittance of the impinging beam will give rise to an effective narrowing of the shadow (penumbra).

An example is given below for the case of shadowing a 2 mil septum for the slow extraction system, with 200 GeV/c protons incident. Whereas this particular system may not be the best arrangement, it shows what sort of improvements are at least possible. The calculations were done by a "Monte Carlo" technique.

We considered an array of tungsten wires, 2 mils in diameter, and spaced at ~150 mil intervals for a length of 2 feet. This gives an effective density of about .24. This corresponds to a collision mean free path of about 280 inches. There was a two-foot space between this "pseudo-septum" and the beginning of the electrostatic septum. The beam was assumed to have an angular divergence of $\pm .02$ mr. Sixty-four percent of the beam incident on the array was coulomb scattered out, with only 5% of the beam making a strong interaction in the tungsten. The 36% which went through the array were sufficiently scattered so that only 15% hit the leading edge of the solid

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septum. Again, two thirds of these left without a strong interaction. The net result was that 90% of the particles incident on the 2 mil wide array did not produce strong interactions in the vicinity of the septum magnet, but were scattered out with rms angles of about .1 mr. Half of these particles will scatter into the ejection channel, and the other half will strike "cleanup" targets in the machine. The result would be an effective extraction efficiency of $\sim .1\%$, since something less than 1% of the beam was expected to impinge on the two mils in any event.

Further studies are being done on this type of pseudo-septum in order to improve it even more. For instance, are the best results obtained with uniform azimuthal and transverse density? The azimuthal density is varied by varying the wire spacing, whereas the transverse density may be varied by interspersing wires of different diameter. Also, the best ratio of drift length between septa to pseudo-septum length has not been determined. Another note at a later date will discuss the design in more detail.

The principal point of the above system is to reduce radiation levels in the neighborhood of the septum extraction magnets. One or two percent more or less doesn't matter for the experimental utilization, but a factor of 10 in the activation of sensitive machine components is very desirable.